[1. (Amended) A method for laser induced breakdown (LIB) of a non-biologic material with a pulsed laser beam, the material being characterized by a relationship of fluence [breakdown] threshold at which breakdown occurs versus laser pulse width that exhibits a [rapid and] distinct change in slope at a characteristic laser pulse width, said method comprising the steps of:

a. generating [a beam of] at least one [or more] laser pulse[s in] which [each pulse] has a pulse width equal to or less than said characteristic laser pulse width; and

b. [focusing said beam] directing said pulse to a point at or beneath the surface of the material.]

[2. The method according to claim 1 wherein the material is a metal, the pulse width is 10 to 10,000 femtoseconds, and the beam has an energy of 1 nanojoule to 1 microjoule.]

[3. The method according to claim 1 wherein the spot size is varied within a range of 1 to 100 microns by changing the f number of the laser beam.]

[4. The method according to claim 1 wherein the spot size is varied within a range of 1 to 100 microns by varying the target position]

[5. The method according to claim 1 wherein the material is transparent to radiation emitted by the laser and the pulse width is 10 to 10,000 femtoseconds, the beam has an energy of 10 nanojoules to 1 millijoule.]

[6. The method according to claim 1 wherein the material is biological tissue, the pulse width is 10 to 10,000 femtoseconds and the beam has an energy of 10 nanojoules to 1 millijoule.]

[7. A method for laser induced breakdown (LIB) of a material with a pulsed laser beam, the material being characterized by a relationship of fluence breakdown threshold versus laser pulse width that exhibits a rapid and distinct change in slope at a predetermined laser pulse width where the onset of plasma induced breakdown occurs, said method comprising the steps of:

a. generating a beam of one or more laser pulses in which each pulse has a pulse width equal to or less than said predetermined laser pulse width obtained by determining

ablation (LIB) threshold of the material as a function of pulse width and by determining where the ablation (LIB) threshold function is no longer proportional to the square root of pulse width; and

b. focusing said beam to a point at or beneath the surface of the material.]

[8. The method according to claim 1 wherein the laser beam has an energy in a range of 10 nanojoules to 1 millijoule.]

[9. The method according to claim 1 wherein the laser beam has an influence in a range of 100 millijoule per square centimeter to 100 joules per square centimeter.]

[10. The method according to claim 1 wherein the laser beam defines a spot in or on the material and the LIB causes ablation of an area having a size smaller than the area of the spot.]

[11. The method according to claim 1 wherein the laser beam has a wavelength in a range of 200 nanometers to 2 microns.]

[12. The method according to claim 1 wherein the pulse width is in a range of a few picoseconds to femtoseconds.]

[13. The method according to claim 1 wherein the breakdown includes changes caused by one or more ionization, free electron multiplication, dielectric breakdown, plasma formation, and vaporization.]

[14. The method according to claim 1 wherein the breakdown includes plasma formation.]

[15. The method according to claim 1 wherein the breakdown includes disintegration.]

[16. The method according to claim 1 wherein the breakdown includes ablation.]

[17. The method according to claim 1 wherein the breakdown includes vaporization.]

[18. The method according to claim 1 wherein the spot size is varied by flexible diaphragm
to a range of 1 to 100 microns.]

[19. The method according to claim 1 wherein a mask is placed in the path of the beam to
block a portion of the beam to cause the beam to assume a desired geometric configuration.]

[20. The method according to claim 1 wherein the laser operating mode is non-TEMoo.]

[21. The method according to claim 2 wherein the laser beam defines a spot and has a lateral gaussian profile characterized in that fluence at or near the center of the beam spot it greater than the threshold fluence whereby the laser induced breakdown is ablation of an area within the spot.]

[22. The method according to claim 22 wherein the spot size is a diffraction limited spot size providing an ablation cavity having a diameter less than the fundamental wavelength size.]

[23. The method according to claim 1wherein the characteristic pulse width is obtained by
determining the ablation (LIB) threshold of the material as a function of pulse width and determining where the ablation (LIB) threshold function is no longer proportional to the square root of pulse width.]

[24. A method for laser induced breakdown of a material which comprises:

a. generating a beam of one or more laser pulses in which each pulse has a pulse width equal to or less than a pulse width value corresponding to a change in slope of a curve of fluence breakdown threshold (F_{th}) as a function of laser pulse width (T), said change occurring at a point between first and second

portions of said curve, said first portion spanning a range of relatively long pulse width where F_{th} varies with the square root of pulse width ($T^{1/2}$) and said second portion spanning a range of short pulse width relative to said first portion with a F_{th} versus T slope which differs from that of said first portion; and

b. focusing said one or more pulses of said beam to a point at or beneath the surface of the material.]

[25. The method according to claim 24 and further including:

a. identifying pulse width start point;

b. focusing the laser beam initial start point at or beneath the surface of the material; and

c. scanning said beam along a predetermined path in a transverse direction.]

[26. The method according to claim 24 and further including:

a. identifying a pulse width start point;

b. focussing the laser beam initial start point at or beneath the surface of the material; and

c. scanning said beam along a predetermined path in a longitudinal direction in the material to a depth smaller than the Rayleigh range.]

[27. The method according to claim 24 wherein the breakdown includes changes caused by one or more of ionization, free electron multiplication, dielectric breakdown, plasma formation, and vaporization.]

[28. The method according to claim 24 wherein the breakdown includes plasma formation.]

[29. The method according to claim 24 wherein the breakdown includes disintegration.]

[30. The method according to claim 24 wherein the breakdown includes ablation.]

[31. The method according to claim 24 wherein the breakdown includes vaporization.]

[32. The method according to any one of claims 1, 2, 5 or 24 wherein said beam is obtained by chirped-pulse amplification (CPA) means comprising means for generating a short optical pulse having a predetermined duration; means for stretching such optical pulse having a predetermined duration; means for amplifying such time-stretched optical pulse including solid state amplifying media; and means for recompressing such amplified pulse to its original duration.]

[33. (Amended) A method for laser induced breakdown (LIB) of a non-organic material with a pulsed laser beam, the material being characterized by a relationship of fluence [breakdown] threshold at which breakdown occurs versus laser pulse width that exhibits a [rapid and] distinct change in slope at a predetermined laser pulse width where the onset of plasma induced breakdown occurs, said method comprising the steps of:

a. generating [a beam of] at least one [or more] laser pulse[s in] which [each pulse] has a pulse width equal to or less than said predetermined laser pulse width; and
b. [focusing said beam] directing said pulse to a point at or beneath the surface of the material so that the laser beam defines a spot and has a lateral gaussian profile characterized in that fluence at or near the center of the beam spot is greater than the threshold fluence whereby the laser induced breakdown is ablation of an area within the spot.]

[34. The method according to claim 33 wherein the spot size is a diffraction limited spot size providing an ablation cavity having a diameter less than the fundamental wavelength size.]

[35. (Amended) A method for laser induced breakdown (LIB) of a non-biologic material with a pulsed laser beam, the material being characterized by a relationship of fluence [breakdown] threshold at which breakdown occurs versus laser pulse width that exhibits a [rapid and] distinct change in slope at a predetermined laser pulse width where the onset of plasma induced breakdown occurs, said method comprising the steps of:

a. generating [a beam of] at least one [or more] laser pulse[s in] which [each pulse] has a pulse width equal to or less than said predetermined laser pulse width; and
b. [focusing said beam] directing said pulse to a point at or beneath the surface of the

material [which is biological tissue], the pulse width is 10 to 10,000 femtoseconds and the beam has an energy of 10 nanojoules to 1 millijoule.]

[36. A method for laser Induced breakdown LIB) of a material by plasma formation with a pulsed laser beam, the material being characterized by a relationship of fluence breakdown threshold versus laser pulse width that exhibits a distinct change in slope at a characteristic laser pulse width, said method comprising the steps of:

a. generating a beam of one or more laser pulses in which each pulse has a pulse width equal to or less than said characteristic laser pulse width, said characteristic pulse width being defined by the ablation (LIB) threshold of the material as a function of pulse width where the ablation (LIB) threshold function is no longer proportional to the square root of pulse width; and

b. focusing said beam to a point at or beneath the surface of the material and inducing breakdown by plasma formation in the material.]

[37. (Amended) A method for laser induced breakdown of a material which comprises:

a. determining, for a selected material, characteristic curve of fluence breakdown threshold (F_{th}) as a function of the square root of laser pulse width;

b. identifying a pulse width value on said curve corresponding to a [rapid and] distinct change in [slope of said F_{th} versus pulse width curve] the relationship between the fluence breakdown and the square root of pulse width characteristic of said material;

c. generating a beam of one or more laser pulses, said pulses having a pulse width at or below said pulse width value corresponding to said distinct change in slope; and

d. [focusing] directing said one or more pulses of said beam to a point at or beneath the surface of the material.]

[38. The method according to claim 37 and further including:

a. identifying a pulse width start point;

b. focusing the laser beam initial start point at or beneath the surface of the material; and

c. scanning said beam along a predetermined path in a transverse direction.]

[39. The method according to claim 37 and further including:

a. identifying a pulse width start point;

b. focusing the laser beam initial start point at or beneath the surface of the material; and

c. scanning said beam along a predetermined path in a longitudinal direction in the material to a depth small than the Rayleigh range.]

[40. The method according to claim 37 wherein the breakdown includes changes caused by one or more of ionization, free electron multiplication, dielectric breakdown, plasma formation, and vaporization.]

[41. The method according to claim 37 wherein the breakdown includes plasma formation.]

[42. The method according to claim 37 wherein the breakdown includes disintegration.]

[43. The method according to claim 37 wherein the breakdown includes ablation.]

[44. The method according to claim 37 wherein breakdown includes vaporization.]

[45. The method according to any one of claims 35, or 37 wherein said beam is obtained by chirped-pulse amplification (CPA) means comprising means for generating a short optical pulse having a predetermined duration; means for stretching such optical pulse in time; means for amplifying such time-stretched optical pulse including solid state amplifying media; and means for recompressing such amplified pulse to its original duration.]

improper per 37CFR 1.177(b) CS

New claims 46 to 54 have been added.

[46. A method for laser induced breakdown (LIB) of a metallic material with a pulsed laser beam, the material being characterized by a relationship of fluence threshold at which breakdown occurs versus laser pulse width that exhibits a distinct change in slope at a characteristic laser pulse width, said method comprising the steps of:

generating at least one laser pulse which has a pulse width equal to or less than said characteristic laser pulse width, said pulse having a width between 10 and 10,000 femtoseconds, and the pulse has an energy of 1 nanojoule to 1 microjoule; and

directing the pulse to a point at or beneath the surface of the material.]

[47. A method as in claim 46 wherein said beam is obtained by chirped pulse amplification (CPA) means comprising means for generating a short optical pulse having a predetermined duration;

means for stretching such optical pulse in time;

means for amplifying such stretched optical pulse including solid state amplifying media; and

means for recompressing such amplified pulse to its original duration.]

[48. A method for laser induced breakdown (LIB) of a material transparent to radiation with a pulsed laser beam, the material being characterized by a relationship of fluence threshold at which breakdown occurs versus laser pulse width that exhibits a distinct change in slope at a characteristic laser pulse width, said method comprising the steps of:

generating at least one laser pulse which has a pulse width equal to or less than said characteristic laser pulse width, where the laser pulse width is 10 to 10,000 femtoseconds and the laser pulse has an energy of 10 nanojoules to 1 millijoule; and

directing the pulse to a point at or beneath the surface of the material.]

[49. A method as in claim 48 wherein said beam is obtained by chirped pulse amplification (CPA) means comprising means for generating a short optical pulse having a predetermined duration;

improper per 37 CFR 1.177(b) EST

means for stretching such optical pulse in time;

means for amplifying such stretched optical pulse including solid state amplifying media; and

means for recompressing such amplified pulse to its original duration.]

[50. A method for laser induced breakdown (LIB) of a material with a pulsed laser beam, the material being characterized by a relationship of fluence threshold at which breakdown occurs versus the square root of laser pulse width that exhibits a distinct change in slope at a characteristic laser pulse width;

determining the ablation (LIB) threshold of the material as a function of pulse width and determining where the ablation (LIB) threshold function is no longer proportional to the square root of pulse width;

generating at least one laser pulse which has a pulse width equal to or less than the characteristic pulse width; and

directing the pulse to a point at or beneath the surface of the material.]

[51. A method of optimally selecting a pulse width and fluence for a pulsed laser beam such that the pulsed laser induces laser induced breakdown (LIB) of a material, the material being characterized by a relationship of fluence threshold at which breakdown occurs versus the square root of laser pulse width comprising the step of identifying where the relationship between fluence threshold and the square root of pulse width exhibits a distinct change in slope and selecting the pulse width and fluence level associated with the distinct change in slope and directing the pulse at a point at or beneath the surface of the material.]

[52. The method as in claim 51 wherein the material is non-organic.]

[53. A method as in claim 51 wherein the material is organic.]

[54. A method for laser induced breakdown of a material with a pulsed laser beam, the material

being characterized by a relationship of fluence threshold at which breakdown occurs versus the square root of laser pulse width that exhibits a distinct change in slope at a characteristic pulse width, said method comprising the steps of:

improper per 37 CFR 1.177(b)

selecting a pulse width and fluence which is equal to or less than the distinct change in slope;

generating at least one laser pulse which has a pulse width equal to or less than the characteristic laser pulse width and fluence; and

directing said pulse to a point at or beneath the surface of a material.]

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46 ~~58.~~ A method of ablating or changing properties in structure of non-biologic materials (LIB) with a pulsed laser beam, said method comprising the steps of:
generating a beam of one or more laser pulses having a pulse width approximately equal to or less than a pulse width at which LIB becomes essentially accurate; and
directing said beam to the material.

47 ~~59.~~ A method of ablation or changing properties in structure of non-biologic materials (LIB) in a volume characterized by a maximum dimension with a pulsed laser beam comprising:
generating a pulsed laser beam characterized by a wavelength of operation that is greater than said dimension; and directing said beam to the material.

48 ~~60.~~ A method of ablation or changing properties in structure of non-biologic materials with a pulsed laser beam comprising:
generating a pulsed laser beam having at least one pulse with a pulse width sufficiently short that the size of the feature created in the material is not substantially limited by thermal diffusion in the material; and directing said beam to the material.

49 ~~61.~~ A method of ablation or changing properties in structure of non-biologic materials characterized by a thermal diffusivity, D, with a pulsed laser beam having a pulse width, T, said method comprising the steps of:
generating a beam of one or more laser pulses having a pulse width sufficiently short so that the thermal diffusion length $l_{th}=Dt^{1/2}$ in the material is significantly smaller than the absorption depth (1/a), where a is the absorption coefficient for the radiation; and
directing said beam to the material.

50 ~~62.~~ A method of ablation or changing properties in structure of non-biologic materials (LIB) with a pulsed laser beam characterized by a beam shape and a fluence comprising,
generating a beam having at least one pulse with a pulse width sufficiently short so that the affected area is substantially determined solely by the beam shape and fluence in relation to the threshold for LIB; and
directing said beam to the material.

Rl 2 e

51 ~~63.~~ The method according to any of claims 58-62 wherein the material comprises one or more of an opaque material and a transparent material.

52 ~~64.~~ The method according to any of claims 58-62 wherein the material comprises one or more of a metal, a dielectric, and a semiconductor material.

Sub a1

53 ~~65.~~ The method according to claim 64 wherein the material comprises at least two layers and LIB substantially affects one layer and not the other.

54 ~~66.~~ The method of claim 65 wherein the material comprises a layer of metal on glass and LIB is induced in the layer of metal.

55 ~~67.~~ The method of any of claims 58-62 wherein LIB is induced on the surface of the material.

56 ~~68.~~ The method of any of claims 58-62 wherein LIB is induced beneath the surface of the material.

57 ~~69.~~ The method of any of claims 58-62 comprising irreversibly changing a property of the material.

58 ~~70.~~ The method of claim 69 in which the step of irreversibly changing includes one or more of melting and vaporization.

59 ~~71.~~ The method of claim 68 comprising irreversibly changing a property of the material.]

60 ~~72.~~ The method of claim 71 in which the step of irreversibly changing includes one or more of melting and vaporization.

61 ~~73.~~ The method of claim 68 in which LIB causes thermal-physical changes in state, leading to an irreversible change in the material.

62 ~~74.~~ The method of claim 67 in which the thermal-physical changes in state includes one or more of melting and vaporization.

63 ~~75.~~ The method of any of claims 58-62 in which LIB includes changes caused by one or more of ionization, free electron multiplication, dielectric breakdown, plasma formation, and vaporization.

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64 ~~76~~. The method according to any of claims 58-62 comprising generating a short optical pulse having a predetermined duration; stretching such optical pulse in time; amplifying such time-stretched optical pulse, and recompressing such amplified pulse to a pulse width.

65 ~~77~~. The method according to any of claims 58-62 comprising scanning the beam along a predetermined path along the surface of the material.

66 ~~78~~. The method according to any of claims 58-62 comprising scanning the beam along a predetermined path beneath the surface of the material.

67 ~~79~~. The method according to any of claims 58-62 comprising scanning the beam along a predetermined path beneath the surface of the material to induce LIB therein to a depth smaller than the Rayleigh range.

68 ~~80~~. The method according to any of claims 58-62 comprising LIB of a material used in one of micromachining, integrated circuit manufacture and encoding data in data storage media.

69 ~~81~~. The method according to any of claims 58-62 comprising LIB in a spot without adversely affecting peripheral areas adjacent to the spot.

70 ~~82~~. The method according to any of claims 58-62 wherein the beam comprises one or more pulses with pulse width in the range of 10 femtoseconds to 10 picoseconds.

71 ~~83~~. The method according to any of claims 58-62 wherein the beam comprises one or more pulses with pulse energy in the range of 1 picojoule to 1 joule.

72 ~~84~~. The method according to any of claims 58-62 wherein the repetition rate is between one pulse per second and 100 million pulses per second.

73 ~~85~~. The method according to any of claims 58-62 wherein the beam comprises one or more pulses with a central wavelength selected from at least one of the following ranges: 100 nm to 200 nm, 200 nm to 300 nm, 300 nm to 700 nm, 700 nm to 1000 nm, 1000 nm to 1100 nm, 1100 nm to 1400 nm, 1400 nm to 1600 nm, 1600 nm to 2000 nm.

74 ~~86~~. The method according to claim 79 wherein the beam comprises one or more pulses with pulse width in the range of 10 femtoseconds to 10 picoseconds.

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75 ~~87~~. The method according to claim 79 wherein the beam comprises one or more pulses with pulse energy in the range of 1 picojoule to 1 joule.

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76 ~~88~~. The method according to according to claim 79 wherein the repetition rate is between one pulse per second and 100 million pulses per second.

77 ~~89~~. The method according to according to claim 79 wherein the beam comprises one or more pulses with a central wavelength selected from at least one of the following ranges: 100 nm to 200 nm, 200 nm to 300 nm, 300 nm to 700 nm, 700 nm to 1000 nm, 1000 nm to 1100 nm, 1100 nm to 1400 nm, 1400 nm to 1600 nm, 1600 nm to 2000 nm.

78 ~~90~~. A method for laser induced breakdown (LIB) of a non-biologic opaque or transparent material with a pulsed laser beam, the material being characterized by a relationship of fluence threshold at which breakdown occurs versus laser pulse width that exhibits a distinct change in slope at a characteristic laser pulse width, said method comprising the steps of:

generating at least one laser pulse which has a pulse width equal to or less than said characteristic laser pulse width; and

directing said pulse to a point at or beneath the surface of the opaque or transparent material.

79 ~~91~~. A method for laser induced breakdown (LIB) of a metal layer on a glass substrate with a pulsed laser beam, the metal being characterized by a relationship of fluence threshold at which breakdown occurs versus laser pulse width that exhibits a distinct change in slope at a characteristic laser pulse width, said method comprising the steps of:

generating at least one laser pulse which has a pulse width equal to or less than said characteristic laser pulse width; and

directing said pulse to a point at or beneath the surface of the metal.

80 ~~92~~. A method for laser induced breakdown (LIB) of a first layer of non biologic material on another layer of non biologic material with a pulsed laser beam, without substantially affecting the first layer, the first layer being characterized by a relationship of fluence threshold at which breakdown occurs versus laser pulse width that

Sub a1

exhibits a distinct change in slope at a characteristic laser pulse width, said method comprising the steps of:

generating at least one laser pulse which has a pulse width equal to or less than said characteristic laser pulse width; and

directing said pulse to a point at or beneath the surface of the first layer.